

1 CLAIMS:

2 1. A method of incorporating nitrogen into a silicon-oxide-
3 containing layer, comprising:

4 exposing the silicon-oxide-containing layer to activated nitrogen
5 species from a nitrogen-containing plasma to introduce nitrogen into the
6 layer; the layer being maintained at less than or equal to 400°C during
7 the exposing; and

8 thermally annealing the nitrogen within the layer to bond at least
9 some of the nitrogen to silicon proximate the nitrogen.

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11 2. The method of claim 1 wherein the layer is maintained at
12 a temperature of from 50°C to 400°C during the exposing.

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14 3. The method of claim 1 wherein the plasma is maintained
15 with a power of from about 500 watts to about 5000 watts during the
16 exposing.

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18 4. The method of claim 1 wherein the plasma is maintained
19 with a power of from about 500 watts to about 3000 watts during the
20 exposing.

1 5. The method of claim 1 wherein the exposing occurs within
2 a reactor, and wherein a pressure within the reactor is from about
3 5 mTorr to about 10 mTorr during the exposing.

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5 6. The method of claim 1 wherein the exposing occurs for a
6 time of less than or equal to about 1 minute.

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8 7. The method of claim 1 wherein the exposing occurs for a
9 time of from about 3 seconds to about 1 minute.

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11 8. The method of claim 1 wherein the exposing occurs for a
12 time of from about 10 seconds to about 15 seconds.

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14 9. The method of claim 1 wherein the annealing comprises
15 rapid thermal processing at a ramp rate of at least about 50°C/sec to
16 a temperature of less than 1000°C, with such temperature being
17 maintained for at least about 30 seconds.

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19 10. The method of claim 1 wherein the annealing comprises
20 thermal processing at temperature of less than 1100°C for a time of at
21 least 3 seconds.

11. A method of forming a nitrogen-enriched region within a silicon-oxide-containing layer, comprising:

providing the silicon-oxide-containing layer over a substrate; the layer having an upper surface above the substrate and a lower surface on the substrate;

exposing the layer to activated nitrogen species from a nitrogen-containing plasma to introduce nitrogen into the layer and form a nitrogen-enriched region, the nitrogen enriched region being only in an upper half of the silicon-oxide-containing layer; and

thermally annealing the nitrogen within the nitrogen-enriched region to bond at least some of the nitrogen to silicon proximate the nitrogen; the nitrogen-enriched region remaining confined to the upper half of the silicon-oxide-containing layer during the annealing; the thermal annealing comprising either (1) thermal processing at a temperature of less than 1100°C for a time of at least 3 seconds, or (2) rapid thermal processing at a ramp rate of at least about 50°C/sec to a process temperature of less than 1000°C, with the process temperature being maintained for at least about 30 seconds.

12. The method of claim 11 wherein the nitrogen-enriched region is formed only in the upper third of the silicon-oxide layer by the exposing.

1 13. The method of claim 11 wherein the nitrogen-enriched region
2 is formed only in the upper third of the silicon-oxide layer by the
3 exposing and remains confined to the upper third of the silicon-oxide
4 containing layer during the annealing.

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6 14. The method of claim 11 wherein the nitrogen-enriched region
7 is formed only in the upper fourth of the silicon-oxide layer by the
8 exposing and remains confined to the upper fourth of the silicon-oxide
9 containing layer during the annealing.

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11 15. The method of claim 11 wherein the nitrogen-enriched region
12 is formed only in the upper fifth of the silicon-oxide layer by the
13 exposing and remains confined to the upper fifth of the silicon-oxide
14 containing layer during the annealing.

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16 16. The method of claim 11 wherein the layer is maintained at
17 a temperature of less than 400°C during the exposing.

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19 17. The method of claim 11 wherein the plasma is maintained
20 with a power of from about 500 watts to about 5000 watts during the
21 exposing.

1 18. The method of claim 11 wherein the exposing occurs within
2 a reactor, and wherein a pressure within the reactor is from about
3 5 mTorr to about 10 mTorr during the exposing.

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5 19. The method of claim 11 wherein the exposing occurs for a
6 time of less than or equal to about 1 minute.

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8 20. A method of forming a transistor, comprising:
9 forming a gate oxide layer over a semiconductive substrate, the
10 gate oxide layer comprising silicon dioxide;

11 exposing the gate oxide layer to activated nitrogen species from a
12 nitrogen-containing plasma to introduce nitrogen into the layer, the layer
13 being maintained at less than or equal to 400°C during the exposing;

14 thermally annealing the nitrogen within the layer to bond at least
15 a majority of the nitrogen to silicon proximate the nitrogen;

16 forming at least one conductive layer over the gate oxide; and
17 forming source/drain regions within the semiconductive substrate;
18 the source/drain regions being gatedly connected to one another by the
19 conductive layer.

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21 21. The method of claim 20 wherein the conductive layer is
22 formed on the gate oxide.
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1 22. The method of claim 20 wherein the conductive layer is
2 formed after the annealing.

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4 23. The method of claim 20 wherein the source/drain regions are
5 formed after the annealing.

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7 24. The method of claim 20 wherein the conductive layer and
8 source/drain regions are formed after the annealing.

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10 25. The method of claim 20 wherein the plasma is maintained
11 with a power of from about 500 watts to about 5000 watts during the
12 exposing.

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14 26. The method of claim 20 wherein the exposing occurs within
15 a reactor, and wherein a pressure within the reactor is from about
16 5 mTorr to about 10 mTorr during the exposing.

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18 27. The method of claim 20 wherein the exposing occurs for a
19 time of less than or equal to about 1 minute.
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1 28. The method of claim 20 wherein the annealing comprises
2 thermal processing at temperature of less than 1100°C for a time of at
3 least 3 seconds.

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5 29. A method of forming a transistor, comprising:
6 forming a gate oxide layer over a semiconductive substrate, the
7 gate oxide layer comprising silicon dioxide; the gate oxide layer having
8 an upper surface and a lower surface;

9 exposing the gate oxide layer to activated nitrogen species from a
10 nitrogen-containing plasma to introduce nitrogen into the gate oxide layer
11 and form a nitrogen-enriched region, the nitrogen enriched region being
12 only in an upper half of the gate oxide layer;

13 thermally annealing the nitrogen within the nitrogen-enriched region
14 to bond at least a majority of the nitrogen to silicon proximate the
15 nitrogen; the nitrogen-enriched region remaining confined to the upper
16 half of the silicon-oxide-containing layer during the annealing;

17 forming at least one conductive layer over the gate oxide layer;
18 and

19 forming source/drain regions within the semiconductive substrate;
20 the source/drain regions being gatedly connected to one another by the
21 conductive layer.
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1 30. The method of claim 29 wherein the nitrogen-enriched region
2 is formed only in the upper third of the silicon-oxide layer by the
3 exposing.

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5 31. The method of claim 29 wherein the nitrogen-enriched region
6 is formed only in the upper third of the silicon-oxide layer by the
7 exposing and remains confined to the upper third of the silicon-oxide
8 containing layer during the annealing.

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10 32. The method of claim 29 wherein the layer is maintained at
11 a temperature of less than 400°C during the exposing.

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13 33. The method of claim 29 wherein the plasma is maintained
14 with a power of from about 500 watts to about 5000 watts during the
15 exposing.

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17 34. The method of claim 29 wherein the exposing occurs within
18 a reactor, and wherein a pressure within the reactor is from about
19 5 mTorr to about 10 mTorr during the exposing.

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21 35. The method of claim 29 wherein the exposing occurs for a
22 time of less than or equal to about 1 minute.
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1 36. The method of claim 29 wherein the annealing comprises
2 thermal processing at temperature of less than 1100°C for a time of at
3 least 3 seconds.

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5 37. The method of claim 29 wherein the conductive layer is
6 formed on the gate oxide.

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8 38. The method of claim 29 wherein the conductive layer is
9 formed after the annealing.

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11 39. The method of claim 29 wherein the source/drain regions are
12 formed after the annealing.

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14 40. The method of claim 29 wherein the conductive layer and
15 source/drain regions are formed after the annealing.

1 41. A transistor structure, comprising:

2 a gate oxide layer over a semiconductive substrate, the gate oxide
3 layer comprising silicon dioxide; the gate oxide layer having a
4 nitrogen-enriched region which is only in an upper half of the gate oxide
5 layer;

6 at least one conductive layer over the gate oxide layer; and

7 source/drain regions within the semiconductive substrate; the
8 source/drain regions being gatedly connected to one another by the
9 conductive layer.

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11 42. The structure of claim 41 wherein the conductive layer
12 comprises conductively-doped silicon.

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14 43. The structure of claim 41 wherein the conductive layer
15 comprises p-type conductively-doped silicon.

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17 44. The structure of claim 41 wherein the nitrogen-enriched
18 region is only in the upper third of the gate oxide layer.

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20 45. The structure of claim 41 wherein the nitrogen-enriched
21 region is only in the upper fourth of the gate oxide layer.

1 46. The structure of claim 41 wherein the nitrogen-enriched
2 region is only in the upper fifth of the gate oxide layer.

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4 47. The structure of claim 41 wherein the gate oxide layer is at
5 least about 5Å thick, and wherein the nitrogen-enriched region is only
6 in the upper 50% of the gate oxide layer.

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